MASTER THESIS

DETERMINANTS OF ENVIRONMENTAL INNOVATION PERFORMANCE ALONG THE VERTICAL SUPPLY CHAIN

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DETERMINANTS OF ENVIRONMENTAL INNOVATION PERFORMANCE ALONG THE VERTICAL SUPPLY CHAIN

The moderation effect of institutional pressure on the relationship between R&D collaboration along the supply chain and environmental innovation performance.

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ABSTRACT

Increasing environmental awareness induces a shift in society that drives firms to become more sustainable. Reacting to governmental pressures and consumer demands, organizations use environmental innovation to convert the inevitable challenges into opportunities. Building on institutional theory, stakeholder theory and existing innovation literature, this study assesses the causal impact of institutional pressure on the effect of research and development collaborations along the supply chain and environmental innovation performance by applying a negative binomial moderation model. By analyzing data from the 2015 release of the German Community Innovation Survey, the results suggest that research and development collaboration both upstream and downstream the supply chain is increasing environmental innovation performance. The findings indicate that, in line with the weak Porter hypothesis, the moderation effect of governmental policies (regulatory pressure) is facilitating environmental innovation performance positively. The moderation effect of market pressure (normative pressure) is yielding mixed results. The findings emphasize the importance of environmental policies in order to increase environmental innovation performance. The thesis contributes to theory development on the conditions that impact environmental innovation performance and to the literature on environmental innovation in general.

Keywords:

Environmental innovation, green supply chain management, institutional theory, Porter hypothesis, open innovation, R&D collaboration, negative binomial regression, moderation

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LIST OF ABBREVIATIONS

CIS	Community Innovation Survey
CSR	Corporate social responsibility
EC	Environmental collaboration
EI	Environmental innovation
IP	Institutional pressure
IRR	Incident rate ratio
NP	Normative pressure
OI	Open innovation
R&D	Research and development
RP	Regulatory pressure
SME	Small- and medium-sized enterprise
VIF	Variance inflation factor

1 INTRODUCTION

The world is facing environmental challenges, including climate change, degradation of natural resources, water scarcity, and air pollution (OECD, 2008). These challenges are global risks that translate into problems with high local impact. One example involves renewable energies in Germany, where green initiatives are starting to gain ground and manifested the share of renewable energies to grow to 37.8% in 2018 (Umweltbundesamt, 2019). However, there are still alarming signals like remaining toxic concentration of air pollution at levels harming the protection of human health or continuously rising sea levels (European Environment Agency, 2017). Due to the importance of environmental degradation these days, a shift towards a more sustainable behavior is visible not only in society but also in politics. On a national level in Germany, as well as in the 2019 European elections, green parties had historic high election results (Brunsden, 2019; Lehmann, 2019).

Firms are centric in the discussion about environmental challenges since they are both one of the main contributors to environmental degradation and an essential source of solutions to fight it (Ozusaglam, 2012; Porter & Van Der Linde, 1995b). In the present business environment, sustainable development is one of the biggest challenges to overcome (Amaeshi, Osuji, & Nnodim, 2008). To antagonize environmental challenges, institutional pressure (IP) is executed in both regulatory as well as normative forms. Whereas regulatory pressure (RP) is pursued by governments, normative pressure (NP) is induced by society. An example of RP is the German Climate Action Plan, introduced by the German government, which imposes a long term strategy to decrease greenhouse gas emissions (BMU, 2019). NP is executed by initiatives like the #FridaysforFuture walkouts that were initiated by Greta Thunberg and mobilize people around the world to claim governments and organizations to fight environmental challenges (Amnesty International, 2019). Recognizing the need for a paradigm shift, the general public is increasingly becoming an impactful body that forces stakeholders, governments, and organizations to act environmentally responsible.

Given the urgency of environmental challenges, sustainability becomes a key driver to innovation. Porter (1991) pioneered in explaining the principle of innovation in the context of environmental policy. Porter and Van Der Linde (1995b) argue that environmental policies can encompass innovation and, thereby, improve a firm's competitiveness. Many authors refer to this kind of innovation as environmental innovation (EI) (Nidumolu, Prahalad, & Rangaswami, 2009). EI differs from conventional innovation in the sense that in the latter case, firms are continually seeking to outperform their competitors in order to achieve economic success. The importance of innovation in this regard is indispensable referring to several studies (Ghisetti & Pontoni, 2015; Hamel, 2008; Tushman & Nadler, 1986). However, for EIs, the reduction of environmental burdens on processes and products is just as substantial (Horbach, Rammer, & Rennings, 2012).

Considering the high complexity of fighting environmental challenges, individual firms can hardly manage the task alone. One approach that starts to emerge is environmental research and development (R&D) collaboration. Since environmental challenges are converging across borders and industries, firms can join forces in tackling them by collaboration. The concept open innovation (OI) helps firms to tap into external R&D capacity and benefit from a more extensive knowledgebase (Chesbrough, 2003; Seuring & Gold, 2013). By sharing R&D capabilities, firms use new variations of depth and breadth of R&D to innovate (Chesbrough, 2003; Katila & Ahuja, 2002). Since IPs are affecting companies and institutions, the relationship of IP and R&D collaboration is a critical component towards a more effective EI creation. Surprisingly, the field investigating the relationship between R&D collaboration and EI under IP is understudied (Gimenez & Tachizawa, 2012; Zhu & Sarkis, 2007). Due to contrasting views between conventional economic theories and the revisionary Porter hypothesis, a closer analysis of the effects of different forms of IP (i.e., RP and NP) in changing scenarios is aspired in this study. The current strand of research on this topic is growing but is not extensive. Furthermore, in the field of research that analyses the relationship between R&D collaboration, EI, and IPs, there are two general limitations. First, the current studies use non-representative samples to assess the relationship. Second, the papers report conflicting outcomes of OI effects for different players along the supply chain. Overall, the moderation effect of IP in the context of R&D collaboration is scarcely researched.

Considering the first limitation, economic literature elaborates on the transferability of R&D collaboration effects from conventional innovations to EIs (Driessen & Hillebrand, 2013; Vachon & Klassen, 2008). However, exemplary for these studies, only a sample of a single industry is used to assess the relationship (Vachon & Klassen, 2008). Regarding the second limitation, several authors find mixed results on the impact of upstream and downstream collaboration partners (De Marchi, 2012; Delmas & Toffel, 2004; Vachon & Klassen, 2008). Especially the empirical findings on R&D collaboration with customers in a sustainability context are discordant. More holistically, the causes why firms engage in EIs is researched by studies on IPs (Berrone, Fosfuri, Gelabert, & Gomez-Mejia, 2013). However, the research fields still lack quantitative evidence and a theoretical framework that elucidates the parameters in relation to each other. To close this research gap, the goal of this paper is to empirically investigate both the effect of OI on EI and the moderating role of IP within the relationship. Thereby, the understanding of conditions that promote EI performance is enhanced. Today, the value of EI finds wide social acceptance, but little is known about the conditions that enforce some firms to innovate more than others (Berrone et al., 2013; Ghisetti & Pontoni, 2015).

To contribute to the growing field of research about EI, this study derives meaningful conjectures by drawing on insights from institutional theory, stakeholder theory, as well as Porter's hypothesis. The thesis argues that R&D collaboration with customers as well as suppliers positively links to EI performance. Customers are essential drivers in creating market awareness and imposing requirements for improved product quality (Del Río, Carrillo-Hermosilla, Könnölä, & Bleda, 2011; Vachon & Klassen, 2008). By contributing knowledge and know-how, suppliers are influencing input materials as well as processes along the upstream part of the supply chain. Furthermore, it is proposed that NP paired with R&D collaboration with customers moderates EI performance more impactful than the effect under RP. Considering the collaboration with suppliers, the proposed effect is mirrored so that the effect is hypothesized to be stronger under RP than under NP. To analyze the hypotheses, this research is conducted by employing cross-sectional data from the 2015 Mannheim Innovation Panel (MIP). The utilized data is explaining the German market.

The remainder of this thesis is structured as follows. This study first provides a theoretical foundation on EIs and institutional theory in section two. In section three, the hypotheses are developed based on the theoretical framework and evidence from prior research. The methodology, including the data description and analytical strategy, is depicted in section four. In section five, a thorough analysis of the results is provided and consequentially discussed to deduce theoretical and practical implications as well as fields for future research in section six. Finally, section seven concludes this study by summarizing the main findings.

2 THEORETICAL BACKGROUND

The following section introduces EI and the theory behind it. Given the continuously increasing importance of EI in achieving sustainability results, the origins and advancements towards conventional innovations are assessed. Furthermore, the concept of institutional theory is explained and expanded by linking it to EI. Institutional theory, with its IPs, is the foundation for the theoretical advancement of the thesis.

2.1 Environmental innovations

Investigating the origin of innovation theory helps understand recent trends in EI. Schumpeter (1934) implemented the concept of innovation as new combinations in an economic system in order to create value. These changes to evoke structural change can originate from different sources such as (1) new products, (2) new methods of production, (3) new markets, (4) new sources of materials, or (5) new industry structures. Although this concept was introduced more than 80 years ago, it is still relevant today (OECD, 2018). The role of EI is tied in with several of the structural changes and extends the notion of using new combinations in order to generate value.

Given the relatively new concept of EI, there is no consensus on one all-encompassing definition. Nevertheless, a widely accepted definition explains EI as *"the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives"* (Kemp & Pearson, 2007, p.7). With this definition, three distinct differences from traditional innovation theory become clear. First, EIs, as opposed to traditional innovations, are also recognized as veritable if it is just a novelty for the company even though it is not a market novelty (Horbach et al., 2012; Rexhäuser & Rammer, 2014). Second, it is insignificant whether the innovative result was considered the main goal or just a by-product for EIs. Most important is the reduction of environmental harm. The emphasize is less on the motivation as on the result. EIs can, therefore, spark out of initiatives to reduce costs or to increase market share. Third, EI needs to have a meaningful impact on reducing environmental burdens (Horbach et al., 2012; Rexhäuser & Rammer, 2014).

Building upon analyses on EI, the driving forces split into two categories on a firm-level: external and internal drivers (Hojnik & Ruzzier, 2016). External factors are further explained as influences that include environmental policies (Desmarchelier, Djellal, & Gallouj, 2013), emission trading (Borghesi, Cainelli, & Mazzanti, 2015), stakeholders (Mondéjar-Jiménez, Vargas-Vargas, Segarra-Oña, & Peiró-Signes, 2013), customer requirements (Kesidou & Demirel, 2012), and market demands (Mondéjar-Jiménez, Segarra-Oña, Peiró-Signes, Payá-Martínez, & Sáez-Martínez, 2015). Internal factors include human resource management (Antonioli, Mancinelli, & Mazzanti, 2013), corporate governance (Amore & Bennedsen, 2016) and technological trajectory (Sáez-Martínez, Díaz-García, & Gonzalez-Moreno, 2016). To put the research into perspective, this study is focusing on specific contributors (environmental policies and stakeholders) of the external drivers of EI.

The rising attention to sustainability in society increased the importance of EIs. As EIs are devoted to the introduction of new products to the market that reduce and eliminate the generation of hazardous substances (Berrone et al., 2013), politics, as well as society, expect EI solutions to be of great value. The description of inclusive innovation by Drucker (1985), who explains innovation as the catalyst producing wealth from resources, therefore needs to be reconsidered on the usage of fewer resources. The challenge is to create value, albeit using fewer resources.

2.2 Institutional theory

Institutionalism expresses organizations' intercourse on social guidelines. When facing external challenges, institutional theory explains the congruent behavior of organizations when confronted with social influence (DiMaggio & Powell, 1983; Scott, 2005). More specifically, organizations take structures, policies, and rules as common guidelines for social behavior (Ritzer, 2007). As a result, different rational parties that try to distinguish themselves from other parties often end up becoming more and more alike (DiMaggio & Powell, 1983). To understand the relationship between institutional theory and organizations, stakeholder theory plays a key role. In this context, companies are no longer just striving to satisfy their shareholders but are trying to contribute to an extensive social group of stakeholders. These actors can proactively motivate organizations to take action on institutional demands or directly collaborate with them to achieve a common goal (Freeman, 1984; Goodman, Korsunova, & Halme, 2017).

To explain the behavior of organizations addressing societal matters, research so far focused on the relationship between IPs and the legitimacy of firms. The results propose that rising IP makes firms more homogenous (Delmas, 2002). Regulations serve as means of guiding organizations and, therefore, represent the executing power that is implementing the underlying institutional intention (Berrone et al., 2013). Particularly, according to Scott (1995), there are three behaviors and corresponding pressures within institutional theory. First, in rational choice theory, organizations are acting out of self-interest. Hence, constructs around the companies, are similarly set-up since everybody tries to maximize their results (Ritzer, 2007). By implementing guiding norms, the organizations' behavior is shaped in the direction to what the institution tries to establish (Berrone et al., 2013). The corresponding pressure that meets this goal is of regulatory nature and often executed by governments. Second, normative theory is based on shared norms and values. Eventual guidelines are not only accepted but internalized by companies and affected parties (Ritzer, 2007). Since organizations have an intrinsic motivation to comply with norms and values, NP from external stakeholders or NGOs is most effective in impacting the firm. Third, the cultural-cognitive theory explains behaviors based on the shared understanding of the participants' surroundings. Organizations are looking to imitate other business leaders to achieve similar results and are, therefore, receptive to mimetic pressure (Scott, 1995). Although all three organizational behaviors are interrelated as a reaction to IPs, in accordance with Scott (2005), this research is concentrating on RP and NP. In an environmental context, findings of prior research show that the first two pressures contribute towards a meaningful change in the institutional environment (Buysse & Verbeke, 2003; Kassinis & Vafeas, 2006).

Today, the more than 30 years ago established institutional theory is confronted with criticism demurring that the theory mires in conservative tradition (Willmott, 2014). More precisely, criticism is concentrating on two themes that serve as the basis for the argument that institutional theory should refocus (Greenwood, Hinings, & Whetten, 2014). First, institutional theory today is focusing heavily on explaining institutions and their processes instead of how the organizations work. Second, institutional theory is built around the notion of understanding organizations by assessing their similarities and thereby induced scholars to ignore differences between organizations (Greenwood et al., 2014). However, in times of globalization, organizations more often feel exposed to similar external challenges, making them search for novel solutions (Ritzer, 2007). As a result, the "new" institutional theory is refined, and evolutionary economists challenge the "old" institutional theory. Single organizations are significant drivers of change in a socio-economic context (Nelson, 2007, 2008). Conforming with this view, institutions are generating learnings and innovations (Rajah Rasiah, 2011). While the "old" institutional theory explains organizations' behavior towards shared norms, the research recently shifted its focus on individual actions of organizations to proact and react to external circumstances (Scott, 2008). A construct of the inter-organizational network derives its strength from strategic actions, including innovations (Palmer & Biggart, 2017).

2.3 The interaction between institutional pressure and EI

Already in 1995, Porter and Van Der Linde advanced the concept around institutional theory with the standpoint that stricter environmental regulation encourages the adoption of social and EIs and can, therefore, be a source of competitive advantage. This new view encourages "win-win" situations, in which environmental effectiveness and financial firm performance can indeed go hand in hand. Within the "old" institutional theory view, financial investments were most often not immediately justifiable (Berrone et al., 2013).

With external pressures and demands that stem from various stakeholders, companies often struggle to drive change through EIs (Hall & Vredenburg, 2003). EIs have the potential to lead to a cleaner and assured world. They are a significant facilitator to environmental as well as economic success. However, in society, EIs are exposed to the so-called "double-externality problem" (Marin, Marzucchi, & Zoboli, 2014; Rennings, 2000). First, value-adding externalities, such as knowledge spillovers, are not internalized by the innovating firms. Second, the reduction of environmental externalities is not valued by the market. As a result, EIs tend to be underinvested (Rennings, 2000).

The importance of EIs becomes apparent when considering that people around the world are affected once no measures to decrease the negative impact on the planet are taken (Hall & Helmers, 2013). As a result, the public's perception is starting to change. Given the importance of finding solutions to environmental issues, different pressures emerged as public interventions to facilitate the implementation of EIs. Porter and Van Der Linde (1995b), Berrone et al. (2013), and Lee and Kim (2011) find that regulations and legislations serve as primary facilitators for EIs. Further, they describe that adaption patterns depend on the company as well as the type of executed pressure. The responses range from a reactive to a proactive stage. The reactive stage will be further analyzed by connecting EIs with RP, whereas the proactive stage is investigated by looking at NP.

Typically, RP is executed by governmental bodies imposing taxes, rules, or laws to decrease environmental pollution (Berrone et al., 2013; Scott, 2005). In Germany, the Renewable Energy Act was introduced in 2000, aiming at doubling the share of renewable energy on a national level by 2010 (Bundesministerium für Wirtschaft und Energie, 2019). Although organizations might not directly realize a short-term effect of EIs, they engage in them to satisfy regulators and to avoid penalties of non-compliance (Berrone et al., 2013; Markman, Espina, & Phan, 2004). Furthermore, EIs can be sparked by IP that ultimately results in competitive advantage (Peloza, 2009; Porter & Van Der Linde, 1995a). Regulations of state organs serve the purpose of making companies see the opportunities that lie in EIs (Dangelico, 2016). The nature of the RP is more connected to reactive responses of companies since initiatives are not implemented out of initially motivated actions (Handfield & Lawson, 2007; Klewitz, Zeyen, & Hansen, 2012; Vachon, 2007; Vachon & Klassen, 2008). In line with Porter and Van Der Linde's (1995b) hypothesis, Dangelico (2016) describes relevant EI outcomes of RP with regards to cost savings, the achievement of competitive advantage, increased market share, and increased reputation.

NPs are guidelines that are imposed by social actors such as NGOs. Often, these pressures relate to legitimacy (Scott, 2005). A German example is the case of German energy supplier RWE, in which environmentalists impose charges against the company to stop clearing forests around their open-pit lignite mine. By putting pressure on the company, the environmental groups are compelling RWE to react (Flauger & Votsmeier, 2019). With NP involved, environmental regulations are translated into proactive behavior to improve a company's innovations and supply chain management (Carter & Dresner, 2001; Nawrocka, 2008).

3 DEVELOPMENT OF HYPOTHESES

By building on institutional and stakeholder theory, the following section is developing testable hypotheses. The first part introduces the main effect of R&D collaboration on supply chain partners. The second part considers the moderating effect of IP on this relationship. Concomitantly, the final part tests Porter's hypothesis in the new composition of variables.

3.1 R&D collaboration along the supply chain and its effect on EI

In complex ecosystems and with pressing demands from various stakeholders, firms are under strain in satisfying all the requisitions by themselves. Companies across industries are battling for a competitive advantage on the newest developments. Factors like shorter innovation cycles and substantial R&D costs give emergence to innovation models like OI (Gassmann & Enkel, 2004). The OI model describes the opening of boundaries between the individual organization and external contributors in order to promote internal innovation. Thereby, the commercialization of own goals next to those of others goes hand in hand (Chesbrough, 2002, 2003). The associated benefits of OI concern shared risk, reduction in development time as well as costs, and access to external resources and skills. However, there are also several connected drawbacks since agency problems can arise, and poorly executed communication can result in information asymmetries as well as high transaction costs (Calantone & Stanko, 2007; Pisano, 1990; West, 2003). In this study, due to the design of the MIP data, R&D collaboration and OI are used interchangeably.

The development of EIs is special because of the novel and multifaced nature and the added layer of complexity compared to conventional innovations. As a result, firms need to look for innovation opportunities outside the sources these originally stem from (Foster & Green, 2000). Especially for innovation in the field of sustainability, active involvement of different networks with governments and NGOs is adjuvant (Sharma, 2002; Van Kleef &

Roome, 2007). With growing awareness for sustainability, stakeholders develop a clear expectation of how the world should become more environmentally friendly. They are, therefore, a valuable source of ideas when it comes to generating innovative and new concepts concerning sustainability (Ayuso, Rodríguez, García-Castro, & Ariño, 2011). Furthermore, in a fast-changing business environment, inputs by external stakeholders contribute towards faster adaptions and more creative innovations (Ayuso et al., 2011). For OI, external information sourcing is vital when implementing innovations and serves as a driver. However, contrarily to the effect of OI on technological innovations, the regiment of literature on the effect of OI towards EI is under-investigated (Ghisetti, 2014). To date, the research on the topic of how R&D collaboration can facilitate EIs focuses on qualitative contributions in the field of innovations and sustainability (Hockerts, Morsing, Eder-Hansen, & Krull, 2008; Holmes & Smart, 2009; Macgregor & Fontrodona, 2008). This study aims to enrich the research with a quantitative analysis of the topic. Furthermore, distinctions between collaborations with different external stakeholders are accounted for by investigating relationships along the vertical supply chain.

The term environmental collaboration (EC) can be explained by direct collaboration with suppliers and customers when developing environmental management practices and sustainable solutions (Vachon & Klassen, 2008). Across the vertical supply chain, this study considers EC with downstream customers and upstream suppliers. Flynn, Huo, and Zhao (2010) define the resulting supply chain integration as the degree to which stakeholders are collaborating strategically to jointly manage intra- and inter-organizational processes. In this thesis, the collaboration is referred to as R&D collaboration.

First, downstream partners are more related to product-based performance (Vachon & Klassen, 2008). Customers are a valuable aid to create awareness for more sustainable products, ultimately resulting in market acceptance (Del Río et al., 2011; Wagner, 2009). Furthermore, in the field of eco-design, Van Hemel and Cramer (2002) and Boks (2006) identify customization as a critical part of stimulating benefits such as image improvement and cost reduction. Additionally, Vachon and Klassen (2006, 2008) assess that customers, involved in product development, improve product quality performance. Combining the current literature, that connects increased awareness, customization, and product quality with the collaboration with customers, indicates that customers are associated with increased EI performance.

Second, upstream partners, in this study embodied by suppliers, are more related to the improvement of processes (Vachon & Klassen, 2008). In a globalized supply chain, the inputs of suppliers heavily influence the resulting product. In order to reach environmental requirements or company-specific goals such as clean production, waste, and carbon reduction or operation optimization, firms collaborate with suppliers. A proven mean of making progress with the discussed focus fields is by jointly developing EIs (Nidumolu et al., 2009; Simpson, Power, & Samson, 2007). Suppliers contribute knowledge and know-how in the implementation of successful EIs (De Marchi, 2012; Vachon & Klassen, 2008). Thus, in a rich collaborative context, the effects of R&D collaboration with upstream suppliers and downstream customers positively influence the environmental impact of processes and products. Descending from this sections' overview, the study examines the following hypotheses.

Hypothesis 1a: R&D collaboration with customers positively influences EI performance.

Hypothesis 1b: R&D collaboration with suppliers positively influences EI performance.

3.2 R&D collaboration under the influence of institutional pressure

In 1995, Porter and Van Der Linde suggest that stricter and more extensive environmental regulations spur innovation. Since then, a large strand of research emerged, testing, extending, and even contradicting parts of the statement. Different propositions were established, ranging from the “weak” over the “narrow” to the “strong” Porter hypothesis (Jaffe & Palmer, 1997). First, the “weak” form states that environmental regulation sparks innovation. Second, the “narrow” version argues that flexible regulatory policies provide more significant incentives than prior versions. Third, the “strong” variant proposes that environmental regulation increases firm competitiveness (Jaffe & Palmer, 1997). However, the Porter hypothesis states that not all regulations necessarily lead to innovation. Instead, in order to do so, they need to be well designed (Ambec, Cohen, Elgie, & Lanoie, 2013). This study focuses on extending the “weak” Porter hypothesis and enriches it by considering its effect on R&D collaboration with partners along the supply chain. Integrating institutional theory to this field of research, the study argues that although subject to the same level of IPs, firms react heterogenous as indicated by the measured EI performance. Differences in the execution of environmental strategies as well as in the collaboration forms might change the effect of EI performance. In order to analyze the type of pressure facilitating EI performance for different collaboration forms, this study investigates the different IPs on upstream and downstream players along the supply chain.

First suggested by Williamson (1991), firms can engage in a hybrid governance structure. This means that organizations can engage in both internalization as well as externalization for environmental improvement since these two streams are not mutually exclusive (Krause, Scannell, & Calantone, 2000; MacDuffie & Helper, 1997; Rao, 2002). Downstream the supply chain, customers increasingly become more aware of companies’ sustainable activities. Their criticism often directs at extending environmental practices along the supply chain (Vachon & Klassen, 2006). However, despite efforts, the incorporation of customers in the introduction of EIs still bears challenges. Ayuso, Rodríguez, García-Castro, and Ariño (2011) explain that knowledge that is gathered and processed from both inside and outside the firm, as opposed to just inside the firm, helps firms to orientate towards broader environmental challenges. Consequently, searching downstream of the value chain for information that can be used to develop innovations is likely to deliver customer-centric tacit knowledge (Von Hippel & Von Krogh, 2006).

EIs are a gateway to a holistic society (Schaltegger & Wagner, 2011; Van Kleef & Roome, 2007). NGOs are essential drivers for the adoption of sustainability strategies, as several studies suggest (González-Benito & González-Benito, 2005, 2010; Sharma & Vredenburg, 1998). A firm that decides to adopt environmental initiatives can actively improve or maintain the relationship to the community it is operating in (Delmas & Toffel, 2004). In recent years, a focus on "life cycle engineering" is growing that is striving to minimize environmental harm. The movement is spearheaded by NGOs and goes hand in hand with global initiatives such as the 'Fair Labor Association' or 'The Global Reporting Initiative' (Leipziger, 2017). The common goal is to facilitate exchange to implement environmental change across organizations (Rivoli & Waddock, 2011). The growing awareness of customers about organizational sustainability initiatives, therefore, is influenced by NP that also operates by creating awareness. Thus, this study hypothesizes that collaborations with customers are influenced more by NP than by RP, as this initiates the customers' awareness for EIs.

Hypothesis 2a: The moderating effect of IP on the relationship between R&D collaboration with customers and EI performance has a stronger impact under NP than under RP.

Upstream the supply chain, suppliers are a major constituent in innovation for the processes. The selection and evaluation of suppliers, however, is complex and not always aligned due to intertwined supplier structures (Chen, Lin, & Huang, 2006). In order for firms to still rely on suppliers to renew and scrutinize environmental processes (Foster & Green, 2000), operations are subject to assessment and monitoring routines both by the firm operating as well as the customer of this firm. Since suppliers are associated with processes, as they typically assimilate raw materials, standardization of outputs is often assured by juridical policies. Examples for internationally accepted and well-known quality benchmarks connected to sustainability are quality management systems according to ISO 9001 or ISO 14001 (Arimura, Darnall, & Katayama, 2011; Johnson, 2015). Generally, regulatory bodies clarify the general perception of green supply chains (Foster & Green, 2000). Thus, this study hypothesizes that the collaboration with suppliers yields better EI performance under RP than under NP.

Hypothesis 2b: The moderating effect of IP on the relationship between R&D collaboration with suppliers and EI performance has a stronger impact under RP than under NP.

Based on the formulated hypotheses, Figure 1 illustrates the suggested research model.

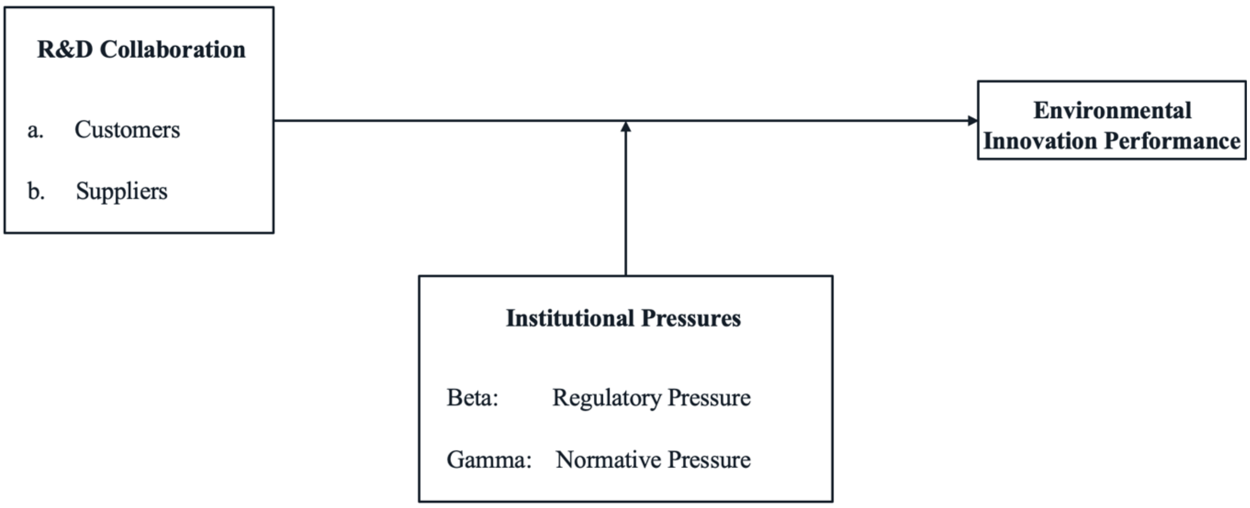

Figure 1. Research model

4 METHODOLOGY

The following analysis facilitates the understanding of the effect of OI on EI as well as the underlying mechanisms. A particular focus lies on the moderating factor of IP within the indicated relationship. This section starts by introducing the dataset and sample and continues to clarify the different measurements. Furthermore, the comprehensive analysis approach to test the developed hypotheses is outlined.

4.1 Data source and sample

The analyzed data for this research is derived from the 2015 MIP, representing the German contribution for the bi-annual pan-European Commission's Community Innovation Survey (CIS). The stratified random sample accounts for the time span from 2012 to 2014 and German firms across 21 sectors (Rammer et al., 2016). The MIP contains information about firms and their innovation activities. Firms take the survey repeatedly, making them familiar with the outline of the survey and allowing comparisons between timespans (Klingebiel & Rammer, 2014). Consequently, the high credibility of the MIP survey is accompanied by a long history of research in the economics of innovation (Czarnitzki & Hottenrott, 2011; Peters, Roberts, Vuong, & Fryges, 2013; Rammer et al., 2016; ZEW, 2019b).

For this thesis, the sample constitutes from the MIP in an education-use file that contains anonymized data (ZEW, 2019a). In 2015, the research included EI activities that are valuable for this thesis. In the case at hand, the sample that constitutes 35,325 firms of which 5,225 responses comprise exhaustive data for further research (Rammer et al., 2016). The response rate of approximately 15% is comparatively low to other European countries. However, the MIP is not mandatory in Germany as opposed to other countries that are contributing to the CIS. The sample of 5,225 firms is further decreased in size to exclude contributions containing missing values. Additionally, outliers are detected using Cook's Distance. The estimation sample for the following research contains 2,581 observations. For a more detailed description of the firm demographics, Appendix A presents the sector allocation.

4.2 Measurements

In the following section, the study describes the variables that are used for statistical analyses in the constructed models. The dependent variable, independent variables, and the moderators are determined by explaining the composition of the variables. Additionally, several control variables are stated and explained by clarifying their operationalization. Appendix B presents an overview of the operationalization of variables that originate from the 2015 MIP.

4.2.1 Dependent variable

EI Performance constitutes the dependent variable in this analysis. The variable is measured by summarizing the responses from the MIP and, therefore, represent both green product as well as process innovations (Rammer et al., 2016). By choosing to measure EI Performance via subjective and personal evaluation of the participants in the study, this thesis reacts to the common criticism that measuring the environmental impact of innovations is often lacking traceability and indications of the relationship (Kleinknecht, Van Montfort, & Brouwer, 2002). Accounting for the timeframe of 2012 to 2014, respondents were asked to indicate whether EIs improve products or processes from zero to two, accounting for "not significant", "yes, but insignificant" and "significant", respectively. There are nine environmental benefits prompted for environmental process innovation and four for environmental product innovations. The accumulation of these scores makes EI Performance a count variable in the analysis that can range from zero to 26. Therefore, due to the design of the MIP data, EI is providing a result that can be interpreted as EI Performance. A higher score can be translated in a high perceived impact of EI for the associated firm.

4.2.2 Independent variable

The independent variable in this research is R&D Collaboration. By investigating the outside-in approach towards OI the focus lies on the impact of collaboration with external partners. The collaborative activity in the research splits up in R&D Collaboration with customers and suppliers. Opposed to Laursen and Salter (2006), this thesis does not treat openness on a continuous scale but implements a dichotomous indicator for OI relating to the collaborator. Therefore, if a firm works together with the corresponding external partners, the variable is coded as 1, otherwise as 0.

4.2.3 Moderator

The moderator to further analyze the main effect is IP. As outlined in theory, the concept of IP contains RP and NP, which are further analyzed in this thesis. In line with Buysse and Verbeke (2003), Guoyou, Saixing, Chiming, Haitao, and Hailiang (2013) and Lee and Kim (2011), this analysis trusts on subjective managerial perceptions towards IPs. RP is proxied by an accumulated count of four different responses from the MIP. The questions are reflecting the firms' perceived importance on the introduction of EIs and include (A) existing environmental regulations, (B) existing environmental taxes, charges or fees, (C) expected environmental regulations in the future, and (D) government grants and subsidies for EIs. Each category can take a score that represents the degree of importance for the firm, ranging from zero to four, equivalent to the responses "not relevant", "low", "medium", "high", respectively. The total count for the grouping variable RP, therefore, can take values ranging from a minimum value of zero to a maximum value of twelve.

NP is measured similarly to RP, hence relying on subjective managerial perceptions and thereby accumulates counts on three MIP questions. These questions relate to (A) current or expected market demand for EIs, (B) improving the enterprise's reputation, and (C) voluntary actions or standards for good environmental practice. Drawing on institutional theory, the aspects of reputation can be related to a firm's legitimacy (Ritzer, 2007). Based on the same method as RP, NP can take counts with a minimum value of zero and up to a maximum value of nine.

As elaborated in-depth in section 5.3, the interpretation of moderation effects in non-linear models requires special attention. Consequently, the moderating variables RP and NP are split into groups for further graphical analysis. First, RP is subdivided into the groups "No", "Weak", "Med" and "High", to indicate the intensity of RP. The associated RP score ranges are 0, 1 – 4, 5 – 8, and 9 – 12, respectively. Second, NP is subdivided into the same groups of "No", "Weak", "Med" and "High" to indicate the strength of pressure in the graphical analysis. The coherent score ranges of NP are 0, 1 – 3, 4 – 6, and 7 – 9, respectively.

4.2.4 Control variables

Several variables are frequently used to control for confounding influences when testing influencing drivers on innovation performance. First, Firm Size is likely to have an influence on innovation performance (Aerts & Schmidt, 2008; Veugelers & Cassiman, 1999). Following the definition by the European Commission (2019), the research includes a dummy variable for firms that employ less than 250 people (indicated as "1") or more than 250 people (expressed as "0"). Second, the variable Sales is explaining the differences in sales, measured in turnover in million euros multiplied by a firm-specific number to keep the data anonymous. Sales impact innovation behavior since firms with slack resources engage in more R&D activities (Hemmelskamp, 1999). Due to the variable's skewness, the natural logarithm is taken to normalize the distribution. Third, Employee Education qualifies as a control variable since innovation performance proves to be influenced by a firm's internal capability to implement new ideas and technologies (Cohen & Levinthal, 1990; Sterlacchini, 2008). Therefore, in the statistical model, this thesis accounts for the share of graduates in a firm. Fourth, Export Intensity is included because the openness and implementation of innovation is likely to be positively impacted by foreign relationships of the firm (Brunnermeier & Cohen, 2003; Rehfeld, Rennings, & Ziegler, 2007). Fifth, Firm Origin, coded as a dummy variable, accounts for the economic differences that are still present in Germany between the East and West (Audretsch, Heger, & Veith, 2015; Fritsch, 2004). Sixth, Industry characteristics are accounted for by including 21 dummies for each of the included industries. As industries differ with regards to environmental pollution, market push and pull factors, and external pressure, scholars suggest controlling for these factors (Leiponen & Helfat, 2010; Walker & Wan, 2012).

4.3 Analytical approach

The analysis of the data starts with a univariate analysis to examine the distribution of the variables. In a second step, a bivariate analysis is performed to investigate the relationships between variables and to test for potential multicollinearity. In the concluding step, the regression analysis based on the theoretical discussion and the proposed hypotheses is conducted. The model regressions are statistically analyzed by using R.

To empirically investigate the hypotheses, the non-negative integer count variables of the dependent variable EI needs to be taken into account. The Poisson model as well as the negative binomial model present frequently used methods for this type of analysis. Considering the restrictive mean-variance assumption of the Poisson model, a statistical test with regards to this ratio provides clarity on the required statistical method (Cameron & Trivedi, 1998; Poisson, 1837). Given that the index of dispersion is 3.90, the skewed nature of the data of EI hints at overdispersion (Hilbe, 2011). Furthermore, as presented in Appendix C, both the Kolmogorov - Smirnov and the Shapiro - Wilk test confirm overdispersion as they significantly reject a normal distribution of EI. The negative binomial model is not as restrictive with regards to overdispersed data and hence is the applicable model for further analyses of the hypotheses.

In the first step, the main effect of the independent variables, R&D Collaboration with customers and R&D Collaboration with suppliers (models 1a & 1b), are tested on the dependent variable EI Performance. The models are illustrated with '*i*' as an index for the firm and 'X^{CTRL}' as a vector including the control variables present in this study: Firm Size, Sales, Employee Education, Export Intensity, Firm Origin, and Industry. To preserve legibility, R&D Collaboration is abbreviated as Collaboration Customers or Suppliers in equations and tables.

$$E\,(EI\ Performance_i \mid \mathrm{X}) = exp\,(\beta_0 + \beta_1\ Collaboration\ Customers_i + \beta' * X^{CTRL} + \varepsilon_i) \quad \textbf{(1a)}$$

$$E\,(EI\ Performance_i \mid \mathrm{X}) = exp\,(\beta_0 + \beta_1\ Collaboration\ Suppliers_i + \beta' * X^{CTRL} + \varepsilon_i) \quad \textbf{(1b)}$$

Second, the moderation effect of IP (split up in RP & NP) on the antecedent relationship is analyzed. In order to assess hypotheses 2a and 2b in R, models 2a beta and 2a gamma, as well as models 2b beta and 2b gamma are consulted and analyzed, respectively. Whereas the variations of hypothesis 2a confront RP and NP in R&D Collaboration with customers, hypothesis 2b investigates the same relationship along R&D Collaborations with suppliers. The following equations represent the parametrizations of the models.

$$\begin{gathered} E\,(EI\ Performance_i \mid \mathrm{X}) = exp\,(\beta_0 + \beta_1\ Collaboration\ Customers_i + \beta_2\ RP_i \\ + \beta_3\ Collaboration\ Customers_i * RP_i + \beta'\, X^{CTRL} + \varepsilon_i) \end{gathered} \quad \textbf{(2a beta)}$$

$$\begin{gathered} E\,(EI\ Performance_i \mid \mathrm{X}) = exp\,(\beta_0 + \beta_1\ Collaboration\ Customers_i + \beta_2\ NP_i \\ + \beta_3\ Collaboration\ Customers_i * NP_i + \beta'\, X^{CTRL} + \varepsilon_i) \end{gathered} \quad \textbf{(2a gamma)}$$

$$\begin{gathered} E\,(EI\ Performance_i \mid \mathrm{X}) = exp\,(\beta_0 + \beta_1\ Collaboration\ Suppliers_i + \beta_2\ RP_i + \\ \beta_3\ Collaboration\ Suppliers_i * RP_i + \beta'\, X^{CTRL} + \varepsilon_i) \end{gathered} \quad \textbf{(2b beta)}$$

$$\begin{gathered} E\,(EI\ Performance_i \mid \mathrm{X}) = exp\,(\beta_0 + \beta_1\ Collaboration\ Suppliers_i + \beta_2\ NP_i + \\ \beta_3\ Collaboration\ Suppliers_i * NP_i + \beta'\, X^{CTRL} + \varepsilon_i) \end{gathered} \quad \textbf{(2b gamma)}$$

5 RESULTS

5.1 Descriptive statistics

The descriptive statistics of the variables are presented in table 1. Only the 21 industry dummy variables are not included in the table to preserve conspectus. The sample size of 2,581 indicates a sufficiently large sample that is representative for the performed tests. As already hinted by choice of the statistical model, the dependent variable EI Performance, is positively skewed (M=2.889, Skewness=1.23). Additionally, RP, NP, and Export Intensity are also positively skewed. Given the skewed distribution of Sales, a logarithmic transformation serves as a means of approximating a normal distribution and to reduce heteroscedasticity (Pearson, 2010). In order to transform values of zero, a constant of one is added to the variable Sales to handle the transformation.

5.2 Bivariate analysis

Given the fact that the variables in the models are not normally distributed, a non-parametric test is used to investigate collinearity. Frequently used methods to test the relationships between non-parametric variables are the Kendall's tau and Spearman's rho rank correlation coefficient. In order to account for errors and discrepancies in the data more sensitively, this study uses the latter. In table 2, the Spearman's rho rank is presented alongside the variance inflation factors (VIF).

Table 1. Descriptive statistics

Variables	N	M	SD	Min.	Max.	Skewness	Kurtosis
EI Performance	2581	2.889	3.358	0	20	1.228	1.013
Collaboration Customers	2581	.0453	.208	0	1	4.374	17.143
Collaboration Suppliers	2581	.0407	.198	0	1	4.653	19.664
Regulatory Pressure	2581	1.966	3.055	0	12.00	1.383	.697
Normative Pressure	2581	1.477	2.182	0	9.00	1.372	.913
Firm Size	2581	.912	.283	0	1	-2.911	6.481
Sales	2581	2.183	1.443	0	6.49	.674	-.360
Employee Education	2581	3.08	2.587	0	8	.445	-1.045
Export Intensity	2581	.134	.236	0	.85	1.875	2.379
Firm Origin	2581	.34	.474	0	1	.670	-1.553

Note: The scale of sales is million €. The variable sales is logarithmically transformed.

The tested effects of OI and the moderating factors of IP are significantly and positively correlated to EI Performance. The relatively high correlations of RP (r_s=.536, p=.001) and NP (r_s=.583, p=.001) towards EI indicate effects in favor of the moderation that is performed in Hypothesis 2a and 2b. Furthermore, the correlation between the different IPs (r_s=.664, p=.001) shows that the pressures are related to each other. However, they do not debilitate the inclusion within the moderation of this study. Moreover, there is a significantly negative correlation of firm size on EI Performance (r_s= -.180, p=.001). Overall, none of the correlations exceed the threshold of 0.7, which would indicate a high correlation (Pearson, 2010). Additionally, the analyzed VIFs show that all tested variables, including the industry dummies that are not reproduced in table 2, are well below the significant threshold of ten and, therefore, show no sign of multicollinearity.

Table 2. Matrix with Spearman's Rho Correlation Coefficients

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	VIF
1. EI										
2. Collaboration Customers	.109***									1.122
3. Cooperation Suppliers	.132**	.247***								1.115
4. Regulatory Pressure	.536***	.014	.084***							1.805
5. Normative Pressure	.583***	.071***	.109***	.664***						1.809
6. Firm size	-.180***	-.031	-.123***	-.147***	-.178***					1.589
7. Sales	.316***	.038.	.121***	.258***	.292***	-.460***				1.976
8. Employee Education	-.002	-.162***	.073***	-.006	.042*	-.044**	.059***			1.489
9. Export Intensity	-.279***	.129***	.163***	.194***	.237***	-.177***	.413***	.136***		1.491
10. Firm Origin	-.086***	.071***	-.003.	-.054***	-.072***	.111***	-.169***	.135***	-.109***	1.095

Note: The variable sales is logarithmically transformed. (Two-tailed) significance levels: (.) 0.1, (*) 0.05, (**) 0.01, (***) 0.001. The values are rounded to three decimals.

5.3 Regression analysis

The following analysis starts by reporting the regression results of the main effect (models 1a & 1b). In a second step, the interaction effects between OI and IP are added and statistically analyzed (models 2a beta, 2a gamma, 2b beta & 2b gamma).

Table 3 summarizes the results of the negative binomial regression examining the link between R&D Collaboration with customers (model 1a) as well as suppliers (model 1b) and EI Performance. In the negative binomial regression, exponential parameter estimates aid the interpretation of the coefficients. For continuous variables, the coefficients can be analyzed as semi-elasticities, whereas for discrete variables, the marginal effect is expressed as $100 * (\exp(\beta) - 1)$. Another way of naming the exponential parameter is the incident rate ratio (IRR), indicating the percentage change in the dependent variable EI Perfromance for each unit increase in the predictor variable. Additionally, to the coefficients, table 3 also indicates the IRRs of the different variables.

The statistical analysis of model 1a shows that R&D Collaboration with customers is significantly positive related to EI ($IRR_{\text{Collaboration Customers}} = 1.575$, $p = .001$). More precisely, if a firm decides to engage in OI with customers, EI Performance increases by 57.5% ($\text{computed as: } 100 * (1.575 - 1)$). This effect indicates that R&D Collaboration with customers has a meaningful impact on EI, thereby supporting H1a. Second, model 1b presents a significantly positive relationship of OI with suppliers related to EI Performance ($IRR_{\text{Collaboration Suppliers}} = 1.301$, $p = .033$). A firm that cooperates with suppliers, therefore, achieves an EI Performance increase of 30.1%. Consequently, hypotheses 1b is supported. Overall, there is statistical evidence, that the proposed effect of both OI with customers as well as with suppliers positively impact the performance of EI. In both discussed models, the control variables Firm Size, Employee Education, and Export Intensity are insignificant. For Firm

Origin, there is a significant basis for reporting that firms in West Germany have a higher EI Performance than their counterparts from East Germany.

The following part focuses on the analysis of the interaction effects between OI with customers as well as suppliers and IP, specified in RP and NP. As emphasized by Ai and Norton (2003), in negative binomial models, it is not possible to interpret the sign, magnitude, or statistical significance of the reported interaction term coefficients. There are four reasons for this implication. First, the interaction coefficient could be nonzero, although the unknown parameter β is zero. Second, the statistical significance cannot be tested with a t-test on the interaction term. Third, unlike linear models, the interaction effect is contingent on the independent variable(s) in multiple regressions. Fourth, depending on the covariate, the sign may differ. Thus, the intuitive interpretation of coefficients does not extend from linear models to non-linear models like the regression at hand (Ai & Norton, 2003). However, there is evidence that a moderation effect is existent in the underlying model. A visualization of predicted values for EI Performance plotted against the interaction variables of OI and further subdivided into groups of IP helps interpreting the moderation effect of the subsequent models.

Before interpreting the relationship graphically, the individual variables of model 2a beta are statistically analyzed. The corresponding IRRs of the variables R&D Collaboration with customers as well as RP (table 4) are both significantly positive ($IRR_{Collaboration\ Customers} = 1.611$, $p = .001$; $IRR_{RP} = 1.159$, $p = .001$). Individually, this translates to a 61.1% increase in EI Performance once a firm engages in OI with customers, as well as a 15.9% increase in EI Performance for every unit increase of RP (RP score from zero to twelve). Figure 2 presents the graphical representation of model 2a beta. When considering the change in predicted EI from no OI with customers to OI with customers in place, the result from the main effect analysis is confirmed, indicating that the customer collaboration improves EI Performance. This finding is enriched by the fact that under each level of RP ("No", "Weak", "Med", and "High"), the effect on EI is higher once OI with customers is involved. R&D collaboration with customers and high RP achieves the highest form of EI Performance.

Table 3. Regression analysis results hypotheses 1a & 1b

Dependent Variable: EI Performance	(1a)	(1b)
Main Effects		
Collaboration Customers	0.454*** (1.575***)	-
Collaboration Suppliers	-	0.263* (1.301*)
Controls		
Firm Size	0.036 (1.037)	0.046 (1.047)
Sales	0.179*** (1.196***)	0.175*** (1.191***)
Employee Education	0.000 (1.000)	0.005 (1.005)
Export Intensity	0.229. (1.258.)	0.234. (1.264.)
Firm Origin	-0.162** (0.851**)	-0.150** (0.860**)
Industries	Yes	Yes
(Intercept)	0.503**	0.498**

Note: Incident rate ratios (IRR) in parentheses. The scale of sales is million €. The variable sales is logarithmically transformed. (Two-tailed) significance levels: (.) 0.1, (*) 0.05, (**) 0.01, (***) 0.001. The values are rounded to three decimals.

Model 2a gamma explains the same effect of OI with customers as 2a beta but pairing it with NP. Individually, both IRRs of OI with customers as well as NP are positively related to EI Performance at high statistical significance ($IRR_{Collaboration\ Customers}$ = 1.698, p = .001; IRR_{NP} = 1.260, p = .001). For OI with customers, this translates to a 69.8% increase in EI Performance once collaboration takes place, whereas the effect on NP indicates a 26% increase in predicted EI Performance for each unit increase in NP (NP score from zero to nine). Assessing the moderation effect, Figure 3 illustrates the graphical context of the model. Contrary to the visualization of model 2a beta, model 2a gamma does not hint at a substantial interaction effect. Under medium NP, the interaction effect is almost not observable. As already introduced in this section, the interpretation of the marginal effects is performed graphically due to the underlying non-linear model. Hence, albeit following the correct statistical procedures, the interpretation is not backed by statistical significance. Still by evaluating the relationships, the interaction of OI with customers and RP is more powerful than under NP as indicated by the magnitude of change and the values for predicted EI. Thus, hypothesis 2a is rejected.

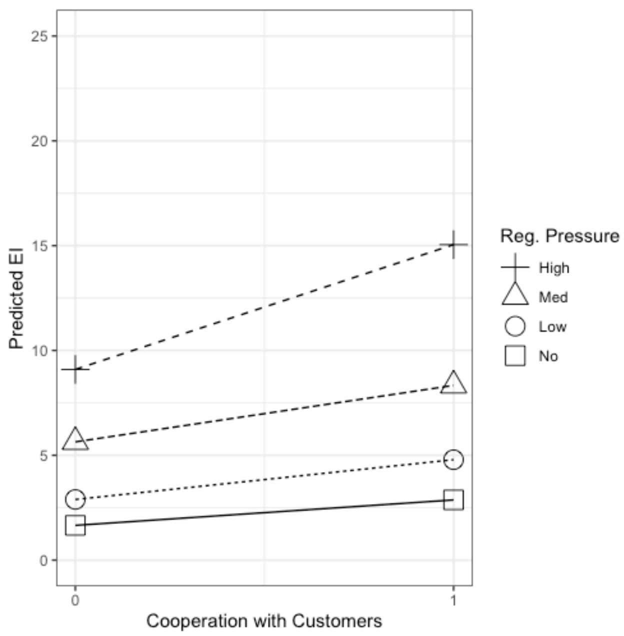

Figure 2. Visualization of predicted values for model 2a beta

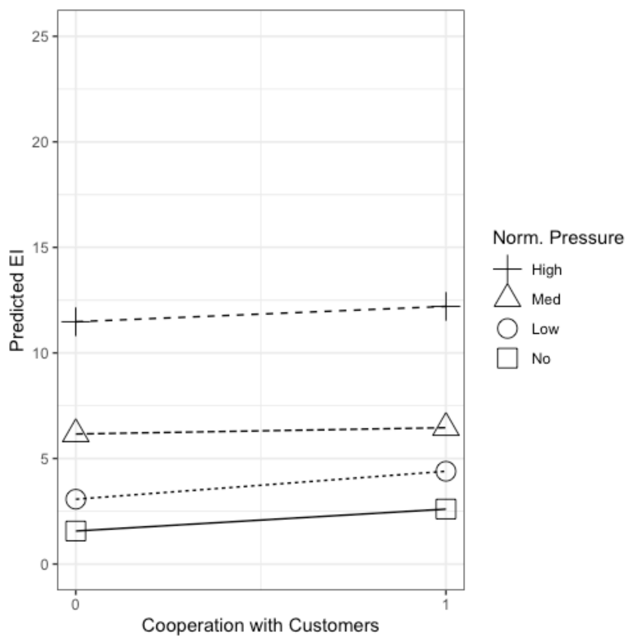

Figure 3. Visualization of predicted values for model 2a gamma

Table 4. Regression analysis results hypotheses 2a & 2b

Dependent Variable: EI Performance	(2a beta)	(2a gamma)	(2b beta)	(2b gamma)
Main Effects				
Collaboration Customers	0.477*** (1.611***)	0.529*** (1.698***)	-	-
Collaboration Suppliers	-	-	0.393** (1.481**)	0.418** (1.51**)
Regulatory Pressure	0.148*** (1.159***)	-	0.150*** (1.162***)	-
Normative Pressure	-	0.231*** (1.260***)	-	0.234*** (1.263***)
Interaction Effects				
*Interaction Customer * RP*	-0.009 (0.991)	-	-	-
*Interaction Customer * NP*	-	-0.071. (0.931.)	-	-
*Interaction Supplier * RP*	-	-	-0.059. (0.943.)	-
*Interaction Supplier * NP*	-	-	-	-0.099* (0.906*)
Controls				
Firm Size	-0.003 (0.997)	0.049 (1.050)	0.001 (1.001)	0.048 (1.049)
Sales	0.115*** (1.122***)	0.113*** (1.120***)	0.113*** (1.120***)	0.109*** (1.115***)
Employee Education	-0.004 (0.996)	-0.014 (0.987)	0.001 (1.001)	-0.009 (0.991)
Export Intensity	0.184 (1.202)	0.161 (1.174)	0.190. (1.209.)	0.163 (1.178)
Firm Origin	-0.121* (0.886*)	-0.115* (0.891*)	-0.110* (0.896*)	-0.105* (0.901*)
Industries	Yes	Yes	Yes	Yes
(Intercept)	0.248	0.193	0.235	0.184

Note: In brackets: Incident rate ratios (IRR). The scale of sales is million €. The variable sales is logarithmically transformed. (Two-tailed) significance levels: (.) 0.1, (*) 0.05, (**) 0.01, (***) 0.001. The values are rounded to three decimals

Considering model 2b beta (table 4), the individual IRRs of OI with suppliers and RP suggest a positive and statistically significant relationship with EI Performance ($IRR_{Collaboration\ Suppliers} = 1.481$, $p = .009$; $IRR_{RP} = 1.162$, $p = .001$). These ratios can be interpreted in the way that a firm that chooses to engage in supplier collaboration achieves 48.1% higher predicted EI Performance. Furthermore, for every unit increase of RP (RP score from zero to twelve), a 16.2% increase in predicted EI Performance can be expected. Figure 4 presents the relationship graphically. The presented visualization indicates that under each level of RP, OI with suppliers results in higher predicted EI Performance than without OI. R&D Collaboration with suppliers and high RP achieves the highest mean value of predicted EI Performance. However, the interaction effect does not seem as substantial as the relationship of R&D collaboration with customers and RP.

The analysis of model 2b gamma discloses significant and positive relationships between OI with suppliers ($IRR_{Collaboration\ Suppliers} = 1.51$, $p = .007$) and NP ($IRR_{NP} = 1.263$, $p =.001$). This implies that R&D Collaboration with suppliers translates into 51% higher predicted EI Performance. Furthermore, for every unit increase in NP (NP score from zero to nine), a 26.3% increase in predicted EI Performance is predicted. Figure 5 visualizes the relationship between the variables. Analyzing the graph explains that if there is no, low, or medium NP, the trend is positive, indicating that the EI Performance is higher with the subsequent pressure intensity and R&D Collaboration with suppliers. Surprisingly, this effect is antagonistic when high NP is considered. In this scenario, the mean predicted EI Performance goes down when cooperating with suppliers. Comparing the factors of RP versus NP, hypothesis 2b is supported since predicted EI Performance scores are more positively moderated under RP than under NP. The negative moderation effect between high NP and OI with suppliers is discussed in-depth in section 6.1.2. Appendix D provides an overview of the key findings that are affecting the hypotheses.

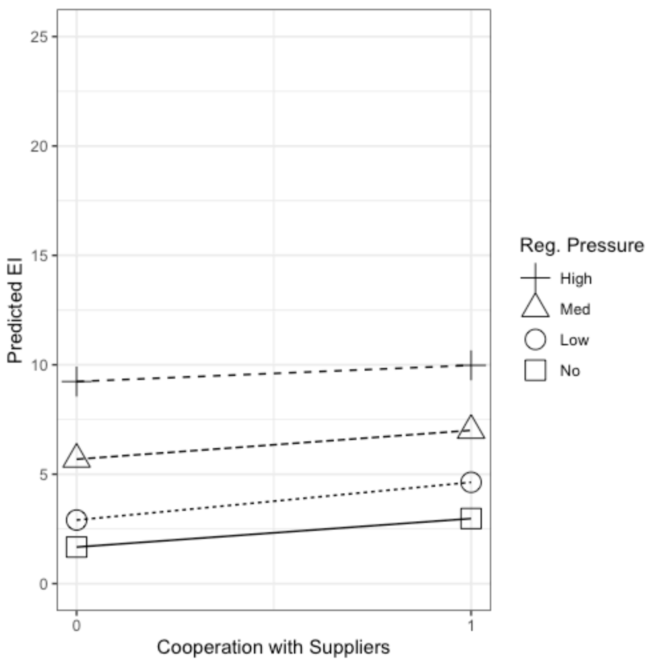

Figure 4. Visualization of predicted values for model 2b beta

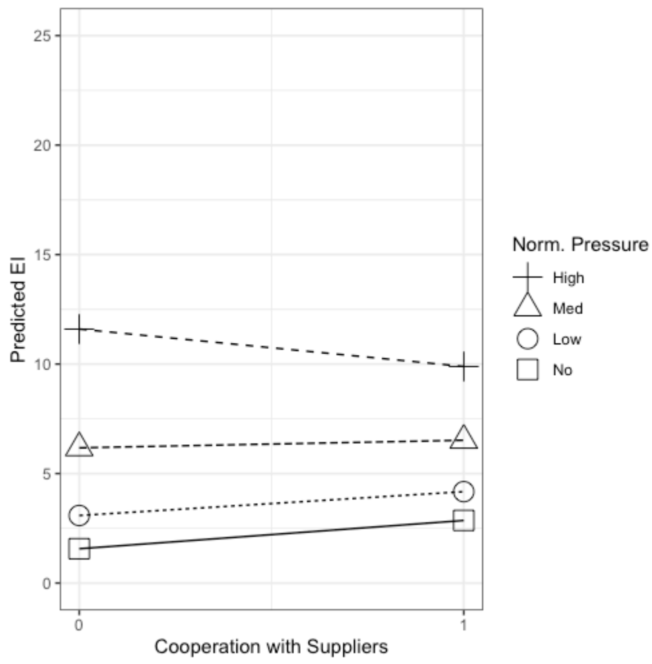

Figure 5. Visualization of predicted values for model 2b gamma

5.4 Robustness checks

In order to test the robustness of the reported results, four robustness checks are performed. On the one hand, these tests scrutinize the statistical suitability of the models. On the other hand, several sample splits enhance the robustness of this study's results in different conditions. The sample splits start with a more holistic view on the industry, continuing with the firm size, and finally examining the R&D investments of the firms. An overview of the results is illustrated in Appendix E.

First, this study replicates the model as a Poisson regression. Although overdispersion is detected, the replication of the regression as a Poisson model serves to challenge the robustness of the performed analysis. Nevertheless, the findings of the main effects remain constant. Furthermore, to confirm that the negative binomial regression is the right statistical model for the study, Appendix F provides an overview of three goodness-of-fit tests, comparing suitability between the Poisson model and the negative binomial model. Akaike's information criterion (AIC) is a fit statistic that adds penalties for model complexity (Hardin & Hilbe, 2014).

Schwartz's Bayesian information criterion (BIC) and the deviance, meaning the generalization of the sum of squares, of both models are additional fit statistics that are taken into account (Beaujean & Morgan, 2016). The model indicating the smallest values on all three fit statistics translates in the best-suited model. As already indicated by the index of dispersion, the negative binomial regression is the appropriate method to use in all of the models.

Second, the regressions are run by only accounting for manufacturing industries and, thereby, excluding service industries. The segmentation aims at testing this study's results for pollution-intensive industries. The subsample contains 1,599 firms. Manufacturing industries are naturally exposed to environmental challenges as they are processing diverse materials and wasteful by-products are generated (Laurent, Olsen, & Hauschild, 2010). Therefore, for manufacturing industries, reducing waste and incorporating innovative ways of developing products constitute a challenge. Akin to the observation of the whole sample, the manufacturing industry subsample confirms the findings. Both directions as well as significance of the coefficients are similar. Solely the significance level of R&D Collaboration with suppliers in model 1b is comparably low ($\beta_{\text{Collaboration } Suppliers} = .213$, $p = .078$). Nevertheless, the findings hold for the subsample.

Third, a sample split is performed to segregate the findings for small- and medium-sized enterprises (SMEs) from findings for larger companies. This sample contains 2,354 SMEs. In order to drive impactful change, SMEs are often considering collaboration to tap into external knowledge flows (Bos-Brouwers, 2010; Lee, Park, Yoon, & Park, 2010). Naturally, SMEs do not have as many resources as larger companies. OI is a way to combine resources, share risks and costs to reach common goals. Especially for SMEs, the findings are therefore tested by using a sample split. As the results show, the general direction and significance of the effects are transferrable from the total sample to the subsample. Solely the significance level of R&D Collaboration with suppliers once again is comparably low ($\beta_{\text{Collaboration } Suppliers} = .280$, $p = .061$).

Fourth, the distinction between firms that engage in R&D by investing in innovation and firms that do not is realized by using a sample split. The regressions of models 1a and 1b are performed with the subsample that incorporates firms that engage in R&D. This sample accounts for 1,145 firms. The robustness check is of interest as the R&D Collaboration effect with both supply chain players is relatively high in the underlying regression analysis. With this additional test, the effect size is attempted to be tested in more depth. The results show that for OI with customers, the effect is smaller and less significant than in the complete sample ($\beta_{\text{Collaboration Customers}} = .212$, $p = .023$). This indicates that part of the reason why the effect in the whole sample is comparably large is because of the comparison between companies that do engage in R&D and companies that do not. The problem is known as endogeneity and explains the phenomenon that the predictor variable is correlated with the error term (Lynch & Brown, 2011). Although several control variables are included, endogeneity cannot be eliminated. Considering OI with suppliers, the coefficient in the subsample is not significant to any generally accepted significance level ($\beta_{\text{Collaboration } \mathit{Suppliers}} = .078$, $p = .414$). Thus, R&D Collaboration with suppliers does not affect EI Performance if a firm invests in R&D on their own. One explanation for this statistical finding is already hinted at in the two prior robustness checks. The relatively low count of 132 firms that engage in R&D Collaboration within the subsample constitutes a challenge when aiming for statistically significant coefficients.

6 DISCUSSION

Based on the stated results, the following section discusses the subsequent hypotheses, starting with the impact of R&D Collaboration on EI Performance in section 6.1.1. Following, section 6.1.2 extends this main effect with the moderating effect of IPs. Already within the discussion, theoretical contributions are outlined per section. In the next step, policy and managerial implications are elaborated. The section about limitations and future research suggestions concludes this chapter.

6.1 Main Findings and theoretical contribution

EI is seen as an essential driver for solving environmental challenges. This study adds to the strand of literature in the field of EI. The outcomes of the thesis contribute to the mixed findings of prior research. In the complex field of EI, a comprehensive understanding is aspired by continuously extending the research. The non-representative samples as well as scarcity of quantitative research make this research valuable from a practical and theoretical perspective. The following sections discuss the hypothesized models and connect these findings with theoretical contributions.

6.1.1 R&D Collaboration as a facilitator for EI Performance

Creating knowledge during the innovation process is vital for firms' competitive advantage (Bierly, Damanpour, & Santoro, 2009; Grant, 1996). Firms realize that this knowledge cannot only emanate from internal processes, leading them to increasingly co-create knowledge with external partners (Hoyer, Chandy, Dorotic, Krafft, & Singh, 2010). Hence, in line with this argumentation, the empirical results show significant support for hypothesis 1a, illustrating that R&D Collaboration with customers influences EI Performance positively. Similarly, hypothesis 1b is also supported, indicating that R&D Collaboration with suppliers improves EI Performance positively. Interestingly, the effect size on EI Performance is more substantial for

R&D Collaboration with customers than with suppliers (i.e., 57.5%, 30.1%, respectively). It is important to note that this assessment is deduced by consulting the magnitude of the coefficient and assessing the significance level within the two regression models. Both terms are more substantial for R&D Collaboration with customers. Part of this difference in magnitude can be attributed to endogeneity and the effect that is explained in the fourth robustness check. In addition, historically, the downstream side of the supply chain impacting environmental challenges is not researched as thoroughly as the upstream side (Vachon & Klassen, 2006). The positive effect found in this study, however, is in line with the research by several authors. R&D Collaboration with customers bears product development that is superior with regards to targeting the right markets and consumers (Ayuso et al., 2011; Horbach et al., 2012; Johansson, 2002; K. H. Lee & Kim, 2011). Considering the complex and radical nature of EIs (De Marchi, 2012; Hart, 2010), external stakeholders can add new points of view and conceptions to the process. As a successful example, hybrid organizations are collaborating with external stakeholders to decrease environmental burdens with a guiding sustainable mission as a foundation (Alexius & Furusten, 2019). According to Alexius & Furusten (2019), hybrid organizations are characterized by (a) many different stakeholders, (b) attempting to solve many conflicting goals and (c) engagement in reciprocal activities. Through multivocal abilities, hybrid organizations have the capabilities to combine corporate social responsibility (CSR) and the generation of profits by implementing sustainable strategies (Alexius & Furusten, 2019).

While this study finds significantly positive effects of both customer as well as supplier collaboration, previous research reports more fragmented results. Generally, several authors find that suppliers are important R&D collaborators for EIs. However, R&D Collaboration with customers does not seem to be differentially important (De Marchi, 2012; Delmas & Toffel, 2004; Simpson et al., 2007; Vachon & Klassen, 2008). Two factors could explain these different findings. First, innovation literature distinguishes between product and process innovations in the research about EIs. Hence, processes permanently play a prominent role since it determines the contribution of environmental burdens (Rennings, 2000). Given the significance of process innovation for environmental amendment, the imbalance between significant collaboration results is reflecting results of conventional collaboration analyses targeted at process innovation. Un and Asakawa (2015) find that solely R&D Collaboration with suppliers is significantly positively related to advancements in EI Performance. Second, while the reported insignificant relationships of R&D Collaboration with customers of the listed studies might appear as if customers do not influence EI Performance, far from being absent, the influence of customers frequently is solely translated through different means. Customer concerns prove to be a driver of environmental management practices (De Marchi, 2012). Furthermore, customer-supplier relationships are mechanisms that impose quality management practices (Anderson, Daly, & Johnson, 1999; Delmas & Toffel, 2004). Since power is usually located downstream in the supply chain (Munson, Rosenblatt, & Rosenblatt, 1999), the influence of customers is translated through giving direction towards partnerships of firms and their suppliers.

The results from this study suggest that, as for conventional innovations, the individual learnings of the contributors are just as crucial as interactive learnings in R&D Collaboration (Von Tunzelmann & Wang, 2007). Especially for the new and complex field of EI, these diverse learnings are vital to sparking new ways of problem-solving. Interestingly, while traditional institutional theory explains that firms become homogenous (DiMaggio & Powell, 1983), the stated effect argues that firms use differences in firm characteristics to solve collective environmental problems. Thus, the approach considers heterogeneous firm properties to identify best-practice solutions. By focusing on heterogeneous characteristics to create value, individual as well as interconnected learnings, such as in OI processes, therefore, explain a valuable theoretical extension towards institutional theory.

In summary, the positive linkage between both R&D Collaboration with customers as well as suppliers, adds support to the concept of stakeholder theory. The common focus of stakeholder theory lies in differing interests between companies and stakeholder groups and managing the conflict effectively (Frooman, 1999). This study shows that the theory expands under the overarching challenge on the environment, which is affecting all stakeholders similarly. Thus, the traditionally internal activities of product and process development gain influence by stakeholder groups such as customers and suppliers in recent trends in qualitative innovation literature (Baldwin & Von Hippel, 2011; Chesbrough, Vanhaverbeke, & West, 2006; Kazadi, Lievens, & Mahr, 2016). The finding of this study confirms these trends in the context of EIs in quantitative form. Collaboration along the supply chain is an opportunity that has the potential to leverage untapped capabilities for EI Performance.

6.1.2 The moderating role of IP and the weak Porter hypothesis

Contrary to the reported importance of NP in the context of EI Performance (Berrone et al., 2013; Murillo-Luna, Garcés-Ayerbe, & Rivera-Torres, 2008), this study cannot find support for a translation of this evidence in the context of R&D Collaboration with customers. Consequently, the study shows no significant support for hypothesis 2a. Indicated by the graphical analysis, high RP appears to have a more prominent impact on EI Performance than NP. There are at least two potential reasons for the diverse outcome.

First, the nature of eco-innovations that enter the market should be radical and systemic in order to induce meaningful change (Boons, Montalvo, Quist, & Wagner, 2013). This kind of sustainable development is fostered by accompanying knowledge flows that take place outside of the firm boundaries (Hansen & Coenen, 2015). However, in the generation of radical innovations, customers often struggle to define their needs. They are better suited to developing incremental innovations instead of radical ones (Olson & Bakke, 2001; Sandberg, 2007). In the interaction with customers, firms need to anticipate the need of the customers in order to establish new products or services that the customer wants (Sandberg, 2007). The customers, therefore, might be very interested in using EI but are not intrinsically proactive in developing radical innovations. An external push is needed to start the innovation process of organizations and customers. The corresponding IP to this process is of regulatory nature.

Second, normative bodies are increasingly competent in shaping regulatory policies. It is essential to look at the underlying principles of these regulatory processes. In essence, regulatory bodies are executing the will of politicians, who are voted by society. The improvement and maintenance of relations to communities is an acknowledged motivation for companies to adopt EIs (Florida & Davison, 2001; Henriques & Sadorsky, 1996). Society and lobby organizations, therefore, might impose a more considerable influence on regulatory policies than it initially seems. That does, however, not reduce the underlying finding that RP is more effective in moderating EI Performance than NP.

The results show that the interaction effect of RP and collaboration with suppliers is mildly but positively moderating the perceived EI Performance. At the same time, under no, low, and medium NP, EI Performance is similar similarly affected as in the conditions of RP. Interestingly, however, under high NP, the relationship reverses and EI Performance goes down once a firm engages in R&D Collaboration with suppliers.

The results of this study support hypothesis 2b, indicating that for R&D Collaboration with suppliers, RP positively moderates EI Performance more prominently than NP. Auxiliary to this finding, prior literature states results that also explain the positive influence of RP on collaboration to external stakeholders upstream the supply chain (i.e., suppliers) (Ghisetti, 2014; Ramanathan, Ramanathan, & Bentley, 2018). A distinguishing factor is the policy design. In accordance with Porter and Van Der Linde (1995b), Ghisetti (2014) underlines the importance of a policy design that is flexible and favors the selection as well as the exploitation of external stakeholder information.

Although the empirical findings support hypothesis 2b, the finding of decreasing EI Performance under high NP and R&D Collaborations with suppliers is worth discussing. In dissonance with the research of Arimura et al. (2011) and Rao (2002), who state that external stakeholders often do not distinguish between the environmental practices of the company and those of its suppliers, collaboration is not enhancing EI Performance in the underlying firm. There are several possible explanations for the finding. Although no research to date investigated this relationship in-depth, a combination of several studies provides possible assertion. Wassmer, Paquin, & Sharma (2014) explain the relationship between normative forces, such as NGOs and firms, as a source of conflict. Many collaborations between NGOs and firms emerge to address formerly discussed environmental issues. High NP alone seemingly spreads uncertainty towards firms. As opposed to RP, there is no need for all suppliers to adhere to NP, implying more time- and resource-intensive monitoring. Along the same lines, Vachon and Klassen (2006) argue that a smaller supplier base favors environmental R&D Collaboration. With many suppliers, retaining an overview can become a challenging task for a firm aspiring to monitor the environmental processes of its suppliers. As Nawrocka, Brorson, and Lindhqvist (2009) point out, suppliers are regularly audited by their customers utilizing interviews and questionnaires. As the negative slope in figure 5 indicates, collaboration is associated with additional coordination and costs (Laursen & Salter, 2006). The results of this thesis show that firms are appreciating the environmental policies by regulatory bodies since they save time and resources formerly spent on the audits. Consequently, in the context of R&D Collaboration with suppliers, high NP impacts EI Performance negatively.

Recapitulatory, considering both R&D Collaboration upstream and downstream the supply chain, RP predominantly promotes overall EI Performance in the tested R&D Collaboration scenarios. This finding provides evidentiary support for the “weak” Porter hypothesis. The principles of the hypothesis explain regulatory policies that are flexible, stringent, and have a high degree of certainty about the policy outline (Porter & Van Der Linde, 1995b). Albeit the findings, a positive or neutral moderating effect of NP is existent in every tested scenario but model 2b – gamma. This indicates that, although the Porter hypothesis is explaining the stronger effect under RP, NP is not negligible.

6.2 Practical implications

The results from the statistical analysis provide practical implications on two fronts. First, policy implications are deduced to facilitate more effective EI implementation. Second, managerial implications are emphasized that aid managers in enforcing a change in their organizations.

6.2.1 Policy implications

Governmental bodies can extract meaningful implications from this research. The importance of RP is unequivocally supported both upstream as well as downstream of the supply chain. For that reason, policymakers can be confident that the policies they initiate have a profound impact on EI Performance of firms. In line with Ghisetti (2014), legislative entities should enforce policies that are favoring the search for external knowledge to facilitate collaboration.

Zooming in and looking at the German ecosystem and the imposed regulations, the following implications can be deducted. German firms are associated as particularly strong environmental innovators. This is not least because of national environmental regulations (Horbach, Oltra, & Belin, 2013). Coupled with NP, the regulatory framework can be considered as quite strong compared to other European or international counterparts (Ekins, 2010; Haščič, Johnstone, & Kalamova, 2009). The results indicate that environmental regulations give assurance about the future development of a sustainable domestic market across industries in Germany. The improvement of these dimensions, therefore, should be a primary goal of future German policy development processes.

Generally, however, given that environmentalism and pressure from NGOs as well as society (i.e., NP) are rising in recent years (Johnson, 2015; Tang, Walsh, Lerner, Fitza, & Li, 2018), policymakers should not disregard these actors. Underestimating the power of NP would be a wrong signal since NGOs and customers have high capabilities in shaping awareness about sustainability (Sharma, 2002). The power in the supply chain is mounted downstream (Munson et al., 1999). Additionally, the knowledge and expertise of NGOs, therefore, enact as an opportunity to bear even more meaningful policies that increase both the quantity and performance of EI.

6.2.2 Managerial implications

Three managerial implications can be derived from this study. First, the importance of R&D Collaboration can be detected by looking at the main effects that are brought forward in this thesis. The significant impact of R&D Collaboration, both upstream and downstream of the supply chain show a positive effect on EI Performance. In addition to the combination of knowledge and expertise, collaborations also reduce risks and costs associated with EI implementation (Chen, Wu, & Wu, 2015; Nidumolu et al., 2009). As the development is a joint effort, the process externalities are shared. Generally, the reduction of risk proves to be a managerial concern, which is also reflected by the predominant influence of RP on EI Performance. In the complex field of environmental challenges, managers are valuing the guidance of policies and versatility of collaborations.

Second, this study attempts to shed light on the question under what conditions firms can benefit from going beyond solely fulfilling RP, hence satisfying NP. It should not be overseen that except for one discussed condition in which NP is connected to a decrease in EI Performance, all other NP levels impact EI Performance positively, although to a lesser extent as regulatory ones. This indicates that there is significant value in incorporating normative motivations, brought forward by NGOs or society. Understanding the motivation behind the pressure and the reasons stakeholders imposing these pressures is vital to design matching strategies. One strategy is to develop stakeholder integration capabilities that connect communication streams with stakeholders along the supply chain (Wolf, 2011). As shown in the negative slope in Figure 4, this could prevent additional costs associated with R&D Collaboration under high NP.

Third, in the quest for organizational change towards more environmental and responsible strategies, studying hybrid organizations can help to deduce best practices. By their multivocal abilities, hybrid organizations are able to react to antithetical demands, including CSR, profit generation, and sustainability (Alexius & Furusten, 2019). The choice of quantity and type of external stakeholders collaboration needs to be considered in order to achieve the highest EI Performance (Juntunen, Halme, Korsunova, & Rajala, 2019). For accomplishing the best EI Performance results through R&D Collaboration, firms need to enact in a culture of OI and social as well as environmental commitment.

6.3 Limitations and future research

Several significant findings can be drawn from this research. In order to ensure legitimate generalizations of the results, the following section addresses several limitations. Some of the data and methodological aspects should be treated with caution. Furthermore, future research opportunities that arise from the limitations are discussed.

6.3.1 Limitations

The data and methodological approach of this study impose certain limitations that need to be considered. First, EI Performance is measured through the MIP questionnaire and is likely to be answered by only one representative of the corresponding firm. Although this practice is common in innovation literature (Anton, Deltas, & Khanna, 2004; Christmann, 2000), perceived scores naturally obtain personal bias. On the one hand, the social desirability biases might lead managers to digress into wishful thinking, thereby not answering the questionnaire based on facts (Berrone et al., 2013). On the other hand, lacking information about all environmental practices of the firm could lead to understated results. Second, the cross-sectional nature of the data only allows distinct insights to EI developments two years or fewer before data collection. However, the research describes that EIs unfold their effect rather in the long-term (Hart & Ahuja, 1996; Horváthová, 2012). Third, this study's findings and implications are based on the MIP, and thus represent German firms. The generalization of the findings is affected by the fact that environmental regulations on a national level differ and that German firms in the national regulatory framework are quite strong in the field of EIs (Ekins, 2010; Haščič et al., 2009). Fourth, the MIP data is anonymized in order to secure data security and integrity. Thus, there is no opportunity to include additional data from other sources to enforce more detailed research (Gottschalk, 2017). Finally, first empirically rectified by Ai and Norton (2003), the complex estimation of the magnitude of interaction effects in non-linear models influenced the discussion of the moderation in this study. Consequently, the results were analyzed graphically and discussed motivated by economic considerations. Detriments in terms of significance estimation, were tolerated to determine trends within the data.

6.3.2 Future research opportunities

In order to approach some of this study's limitations and to expand its research scope, several fields for future studies are identified. First, the estimation of EI Performance should be assessed at a more disaggregated level. By combining subjective and objective (i.e., patent counts) measures, a more comprehensive analysis is possible. Second, to elaborate on the generalization of the data, which is conducted with German firms, to different economies, further empirical research has to replicate or advance the study in different countries. Additionally, a more segmented analysis between industries can provide advanced knowledge about the most effective prerequisites on EI Performance. Third, to not only inspect Porter's "weak" but also "strong" hypothesis, the current research study can be expanded by assessing the financial impact of the different conditions. Given the continuous discussion of whether sustainability and profitability are both achievable simultaneously, research that examines this relationship is valuable. Fourth, to analyze the comparison between RP and NP in further detail, future research can use established statistical methods to compare the variables against each other. In this study's non-linear model, detriments in terms of significance estimation were unavoidable. Finally, to assess the long-term effects of EIs, a longitudinal research design can potentially expand managerial and policy implications. Especially if financial measures are included in the study, long-term performance is a key condition in the field of EI to translate into financial impact (Horváthová, 2012). In summary, the advancements are proposed in order to explore and understand the complex field of EI and its performance. In order to solve environmental issues through innovation, the proposed additional research, just as this study, adds comprehension towards the conditions under which EI is performing best.

7 CONCLUSION

Environmental challenges impose a paradigm shift both in society and business ecosystems. Faced by RP and NP, firms are seen as critical contributors to approach environmental degradation. Accompanied by the challenge of becoming more environmentally friendly, firms prospect several opportunities. By engaging in EI, firms can actively reduce the environmental impact of products and services. Given the importance of successful EI in order to fight climate change, it is vital to understand the constituents that facilitate EI. Although environmental awareness is increasing, empirical research on the conditions that impact EI is still fragmentary given its complex nature. Previous studies are mainly qualitative and do not connect the fields of IPs with R&D Collaboration along the supply chain.

Thus, this study analyses data of the German release of the 2015 CIS to investigate the impact of IP on the relationship between R&D Collaboration along the supply chain and EI Performance. The empirical results provide valuable insights into R&D Collaboration, both upstream and downstream the supply chain. R&D Collaboration with customers as well as suppliers entails a positive influence on EI Performance. In line with the "weak" Porter hypothesis, the analysis of the moderation effect of IP on R&D Collaboration presents evidence that RP is more successful in increasing EI Performance within the collaboration forms.

In summary, the findings present relevant implications for policymaking. Although this thesis is not exempt from limitations, the findings contribute to prior research about EI, institutional theory, and EC along the supply chain. The established importance of RP in the context of encouraging EI should make policymakers confident that imposed policies have a profound impact and motivate to enhance meaningful environmental policies in the future.

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9 APPENDICES

Appendix A – Firm demographics

Sectors

Code*	Sector description	N	Percentage
5-9, 19, 35	Mining	99	4
10-12	Food/Tobacco	123	5
13-15	Textiles	102	4
16-17	Wood/Paper	82	3
20-21	Chemical	80	3
22	Plastics	78	3
23	Glass/Ceramics	64	3
24-25	Metals	217	8
26-27	Electrical Equipment	195	8
28	Machinery	126	5
29-30	Retail/Automobile	57	2
31-33	Furniture/Toys/Medical Technology/Maintenance	154	6
36-39	Energy/Water	168	7
46	Wholesale	101	4
49-53, 79	Transport Equipment/Postal Service	191	7
18, 58-60	Media Services	118	5
61-63	IT/Telecommunications	101	4
64-66	Banking/Insurance	89	3
71-72	Technical Services/R&D Services	143	6
69, 70.2, 73	Consulting/Advertisement	160	6
74, 78, 80-82	Firm-related Services	133	5

*Note: *based on two-digit NACE Rev.2 classification according to European Commission (2008).*

Appendix B – MIP questions for operationalization of variables

Originating MIP Questions

Variables	#	MIP Questions for the Operationalization of the Variable
<u>Independent Variables</u>		
R&D Collaboration	9.1	Did your enterprise co-operate on any of your innovation activities during 2012 to 2014?
	9.2	Please indicate the type of innovation co-operation partner by location.
Customers		▪ Clients or customers from the private sector
		▪ Clients or customers from the public sector
Suppliers		▪ Suppliers of equipment, materials, software, etc.
<u>Dependent Variable</u>		
Environmental Innovation	13.1	During 2012 to 2014, did your enterprise introduce innovations that had any of the following environmental benefits, and if yes, was their contribution to environmental protection rather significant or insignificant?
		▪ Reduced energy use per unit of output
		▪ Reduced material use / use of water per unit of output
		▪ Reduced CO_2 ‚footprint' (total CO_2 production)
		▪ Reduced air pollution (i.e. SOx, NOx)
		▪ Reduced water or soil pollution
		▪ Reduced noise pollution
		▪ Replaced fossil energy sources by renewable energy sources
		▪ Replaced materials by less hazardous substitutes
		▪ Recycled waste, water, or materials for own use or sale
	13.2	During 2012 to 2014, did your enterprise introduce new products or services with the following environmental benefits through the use of these products/services, and if yes, what was their contribution to environmental protection?
		▪ Reduced energy use
		▪ Reduced air, water, soil or noise pollution
		▪ Improved recycling of product after use
		▪ Extended product life through longer-lasting, more durable products

<u>Moderator</u>		
Regulatory Pressure	13.3	During 2012 to 2014, how important were the following factors in driving your enterprise's decisions to introduce environmental innovations? (A) Existing environmental regulations (B) Existing environmental taxes, charges or fees (C) Environmental regulations or taxes expected in the future (D) Government grants, subsidies etc. for environmental innovations
Normative Pressure	13.3	During 2012 to 2014, how important were the following factors in driving your enterprise's decisions to introduce environmental innovations? (E) Current or expected market demand for environmental innovations (F) Improving your enterprise's reputation (G) Voluntary actions or standards for environmental good practice within your sector

Note: the questions are adapted from the 2015 MIP questionnaire.

Appendix C – Tests for overdispersion

	Kolmogorov - Smirnov			Shapiro - Wilk		
	Statistic	*df*	*Significance Level*	*Statistic*	*df*	*Significance Level*
EI Performance	.195	2581	.000	.828	2581	.000

Appendix D – Results overview of hypothesis testing

Results overview

Hypotheses	**Findings**
Hypothesis 1a: R&D collaboration with customers positively influences EI Performance.	Supported
Hypothesis 1b: R&D collaboration with suppliers positively influences EI Performance.	Supported
Hypothesis 2a: The moderating effect of IP on the relationship between R&D collaboration with customers and EI performance has a stronger impact under NP than under RP.	Not Supported
Hypothesis 2b: The moderating effect of IP on the relationship between R&D collaboration with suppliers and EI performance has a stronger impact under RP than under NP.	Supported

Appendix E – Robustness checks

Results of alternative regression models (1/6)

	(1a)				
	Negative Binomial	Poisson	Industry Subset	SME Subset	R&D Subset
Main Effects					
Collaboration Customer	0.454***	0.379***	0.325**	0.499***	0.212*
Collaboration Supplier	-	-	-	-	-
Regulatory Pressure	-	-	-	-	-
Normative Pressure	-	-	-	-	-
Interaction Effects					
*Interaction Customer * RP*	-	-	-	-	-
*Interaction Customer * NP*	-	-	-	-	-
*Interaction Supplier * RP*	-	-	-	-	-
*Interaction Supplier * NP*	-	-	-	-	-
Controls					
Firm Size	0.036	0.004	0.003	-	-0.035
Sales	0.179***	0.171***	0.172***	0.180***	0.103***
Employee Education	0.000	0.002	0.031*	0.001	-0.015
Export Intensity	0.229.	0.152**	0.139	0.268.	0.154
Firm Origin	-0.162**	-0.170***	-0.204**	-0.165**	-0.095
Industries	Yes	Yes	Yes	Yes	Yes
(Intercept)	0.503**	0.569***	0.498*	0.537***	1.285***

Note: The scale of sales is million €. The variable sales is logarithmically transformed. (Two-tailed) significance levels: (.) 0.1, (*) 0.05, (**) 0.01, (***) 0.001. The values are rounded to three decimals.

Results of alternative regression models (2/6)

	(1b)				
	Negative Binomial	Poisson	Industry Subset	SME Subset	R&D Subset
Main Effects					
Collaboration Customer	-	-	-	-	-
Collaboration Supplier	0.263*	0.242***	0.213.	0.280.	0.078
Regulatory Pressure	-	-	-	-	-
Normative Pressure	-	-	-	-	-
Interaction Effects					
*Interaction Customer * RP*	-	-	-	-	-
*Interaction Customer * NP*	-	-	-	-	-
*Interaction Supplier * RP*	-	-	-	-	-
*Interaction Supplier * NP*	-	-	-	-	-
Controls					
Firm Size	0.046	0.014	0.009	-	-0.032
Sales	0.175***	0.169***	0.167***	0.175***	0.101***
Employee Education	0.005	0.006	0.033*	0.006	-0.011
Export Intensity	0.234.	0.146**	0.134	0.278*	0.152
Firm Origin	-0.150**	-0.162***	-0.196**	-0.151*	-0.084
Industries	Yes	Yes	Yes	Yes	Yes
(Intercept)	0.498**	0.559***	0.504*	0.548***	1.291***

Note: The scale of sales is million €. The variable sales is logarithmically transformed. (Two-tailed) significance levels: (.) 0.1, (*) 0.05, (**) 0.01, (***) 0.001. The values are rounded to three decimals.

Results of alternative regression models (3/6)

	(2a beta)			
	Negative Binomial	Poisson	Industry Subset	SME Subset
Main Effects				
Collaboration Customer	0.477***	0.415***	0.366**	0.523***
Collaboration Supplier	-	-	-	-
Regulatory Pressure	0.148***	0.135***	0.137***	0.155***
Normative Pressure	-	-	-	-
Interaction Effects				
*Interaction Customer * RP*	-0.009	-0.000	-0.005	-0.016
*Interaction Customer * NP*	-	-	-	-
*Interaction Supplier * RP*	-	-	-	-
*Interaction Supplier * NP*	-	-	-	-
Controls				
Firm Size	-0.003	-0.003	-0.020	-
Sales	0.115***	0.093***	0.105***	0.114***
Employee Education	-0.004	0.005	0.020	-0.005
Export Intensity	0.184	0.127*	0.136	0.236.
Firm Origin	-0.121*	-0.139***	-0.149**	-0.128*
Industries	Yes	Yes	Yes	Yes
(Intercept)	0.248	0.356***	0.278	0.225

Note: The scale of sales is million €. The variable sales is logarithmically transformed. (Two-tailed) significance levels: (.) 0.1, (*) 0.05, (**) 0.01, (***) 0.001. The values are rounded to three decimals.

Results of alternative regression models (4/6)

	(2a gamma)			
	Negative Binomial	Poisson	Industry Subset	SME Subset
Main Effects				
Collaboration Customer	0.529***	0.454***	0.446**	0.586***
Collaboration Supplier	-	-	-	-
Regulatory Pressure	-	-	-	-
Normative Pressure	0.231***	0.195***	0.207***	0.245***
Interaction Effects				
*Interaction Customer * RP*		-		
*Interaction Customer * NP*	-0.071.	-0.053***	-0.072.	-0.088*
*Interaction Supplier * RP*	-	-	-	-
*Interaction Supplier * NP*	-	-	-	-
Controls				
Firm Size	0.049	0.031	0.085	-
Sales	0.113***	0.091***	0.119***	0.115***
Employee Education	-0.014	-0.003***	0.009	-0.022.
Export Intensity	0.161	0.146**	0.119	0.180
Firm Origin	-0.115*	-0.126***	-0.133*	-0.106.
Industries	Yes	Yes	Yes	Yes
(Intercept)	0.193	0.354***	0.152	0.221

Note: The scale of sales is million €. The variable sales is logarithmically transformed. (Two-tailed) significance levels: (.) 0.1, (*) 0.05, (**) 0.01, (***) 0.001. The values are rounded to three decimals.

Results of alternative regression models (5/6)

	(2b beta)			
	Negative Binomial	Poisson	Industry Subset	SME Subset
Main Effects				
Collaboration Customer	-	-	-	-
Collaboration Supplier	0.393**	0.369***	0.322*	0.381*
Regulatory Pressure	0.150***	0.137***	0.139***	0.156***
Normative Pressure	-	-	-	-
Interaction Effects				
*Interaction Customer * RP*	-	-	-	-
*Interaction Customer * NP*	-	-	-	-
*Interaction Supplier * RP*	-0.059.	-0.048***	-0.046	-0.057
*Interaction Supplier * NP*	-	-	-	-
Controls				
Firm Size	0.001	0.002	-0.020	-
Sales	0.113***	0.092***	0.101***	0.113***
Employee Education	0.001	0.009	0.024.	-0.000
Export Intensity	0.190.	0.143**	0.141	0.240.
Firm Origin	-0.110*	-0.128***	-0.139*	-0.114*
Industries	Yes	Yes	Yes	Yes
(Intercept)	0.235	0.340***	0.278	0.218

Note: The scale of sales is million €. The variable sales is logarithmically transformed. (Two-tailed) significance levels: (.) 0.1, (*) 0.05, (**) 0.01, (***) 0.001. The values are rounded to three decimals.

Results of alternative regression models (6/6)

	(2b gamma)			
	Negative Binomial	Poisson	Industry Subset	SME Subset
Main Effects				
Collaboration Customer	-	-	-	-
Collaboration Supplier	0.418**	0.384***	0.313*	0.398*
Regulatory Pressure	-	-	-	-
Normative Pressure	0.234***	0.197***	0.207***	0.246***
Interaction Effects				
*Interaction Customer * RP*	-	-	-	-
*Interaction Customer * NP*	-	-	-	-
*Interaction Supplier * RP*	-	-	-	-
*Interaction Supplier * NP*	-0.099*	-0.075***	-0.069.	-0.104*
Controls				
Firm Size	0.048	0.031	0.080	-
Sales	0.109***	0.090***	0.113***	0.111***
Employee Education	-0.009	-0.001	0.0120	-0.017
Export Intensity	0.163	0.152**	0.121	0.178
Firm Origin	-0.105*	-0.121***	-0.124	-0.095.
Industries	Yes	Yes	Yes	Yes
(Intercept)	0.184	0.346***	0.159	0.219

Note: The scale of sales is million €. The variable sales is logarithmically transformed. (Two-tailed) significance levels: (.) 0.1, (*) 0.05, (**) 0.01, (***) 0.001. The values are rounded to three decimals.

Appendix F – Goodness-of-fit statistics

Results of Goodness-of-fit statistics (1/2)

	(1a)		(1b)	
	Poisson	NegBin	Poisson	NegBin
AIC	13873.6	11039.03	13908.56	11050
BIC	14031.71	11202.99	14066.67	11213.97
Deviance	8692.3	2854.2	8727.3	2852.7

Note: AIC: Akaike's information criterion; BIC: Schwartz's Bayesian information criterion.

Results of Goodness-of-fit statistics (2/2)

	(2a beta)		(2a gamma)		(2b beta)		(2b gamma)	
	Poisson	NegBin	Poisson	NegBin	Poisson	NegBin	Poisson	NegBin
AIC	12293.91	10657.55	12233.54	10592.17	12341.88	10670.5	12249.41	10600
BIC	12463.73	10833.23	12403.36	10767.85	12511.71	10846.18	12419.23	10775.68
Deviance	7108.6	2960.3	7048.3	2948.5	7156.6	2957.0	7064.1	2948.8

Note: AIC: Akaike's information criterion; BIC: Schwartz's Bayesian information criterion.

10 DECLARATION OF ORIGINALITY

By signing this statement, I hereby acknowledge the submitted thesis, titled “Determinants of environmental innovation performance along the vertical supply chain” to be produced independently by me, without external help.

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